TRADE – TRIGA Accelerator Driven Experiment

The TRADE Working Group

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July 9-10, 2002

TRADE

- The TRADE Working Group:
  - ENEA (+partners: ANSALDO, CERN)
  - CEA
- Set up in February 2001 – First phase of feasibility report: ended July 2001
- ENEA/CEA Managements require further investigations:
  - Safety and Licensing
  - Accelerator and beam line
  - Costs and Schedule
- Second phase of feasibility report: ended March 2002 – Results review by ENEA and CEA management on May 7, 2002
- Still work in progress on specific points (safety case, 3D thermohydraulics of target in natural convection, experimental techniques etc), but no “show-stoppers” foreseen.
- ENEA and CEA ready to go ahead.
- FZK expressed interest in joining the “founding” partners.
- Support of the EU being requested.

TRADE Working Group---Experiments

MUSE and TRADE---Progressive Steps

- MUSE can
  - Investigate source importance effects to 14 MeV
  - Investigate aspects of flux distributions in a fast spectrum, including reaction rates, study decoupling
  - Validate dynamic methods of zero-power reactivity monitoring (a major objective)

TRADE Working Group---Experiments

MUSE and TRADE---(2)

- MUSE cannot
  - Investigate source importance above 14 MeV
  - Investigate power/current/importance relations
  - Study the effects of different buffers at high energy
  - Study dynamic effects with power feedback
  - Study operational procedures (startup/shutdown, reactivity swings)

TRADE Working Group---Experiments

MUSE and TRADE---(3)

* TRADE can
  - Study dynamic effects at power at different subcriticality levels (feedback vs. source effects)
  - Study startup/shutdown scenarios
  - Study current vs control rods for reactivity compensation
  - Validation of beam control/shutdown approach

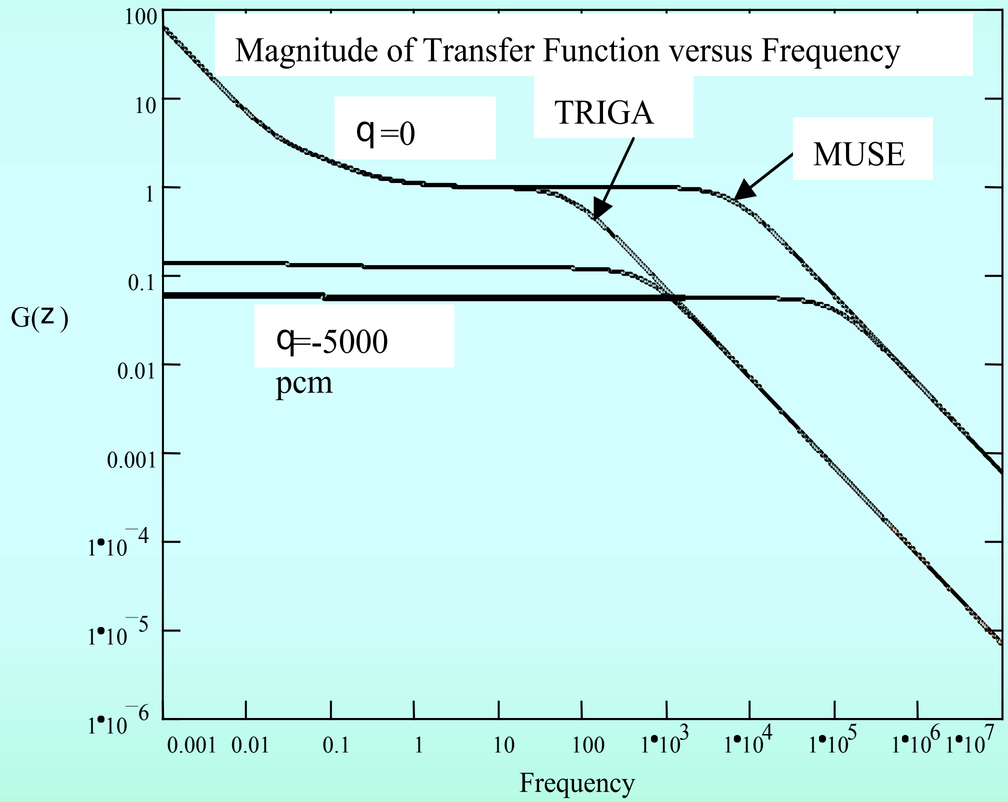
TRADE Working Group---Experiments

MUSE and TRADE---(4)

* TRADE can
    - In general, study all relevant aspects of current/power/importance/control rod relations
    - Be used to test dynamic methods developed in MUSE in a thermal system ("generic validation")
    - Study the effects of different buffers

TRADE Working Group---Experiments

Is a Thermal Reactor Representative?



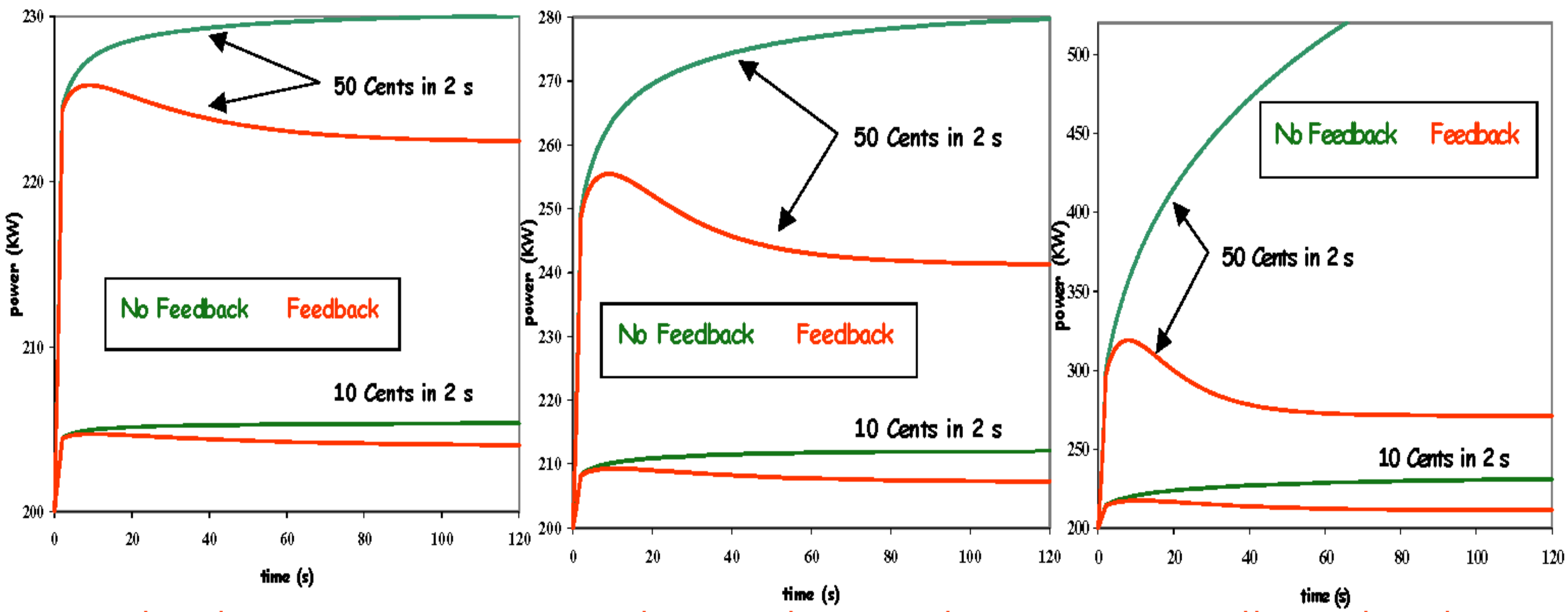
TRADE-Neutronic Design

?

Can we induce transient conditions giving responses representative of the ADS dynamics relevant to higher power systems?

Simulation of reactivity insertion transients for different subcriticality levels (from 200 kW).

TRADE Reference Configuration (-3.81 $) TRADE "High K" Configuration (-1.74$) TRADE "Very High K" Config. (-0.72$)

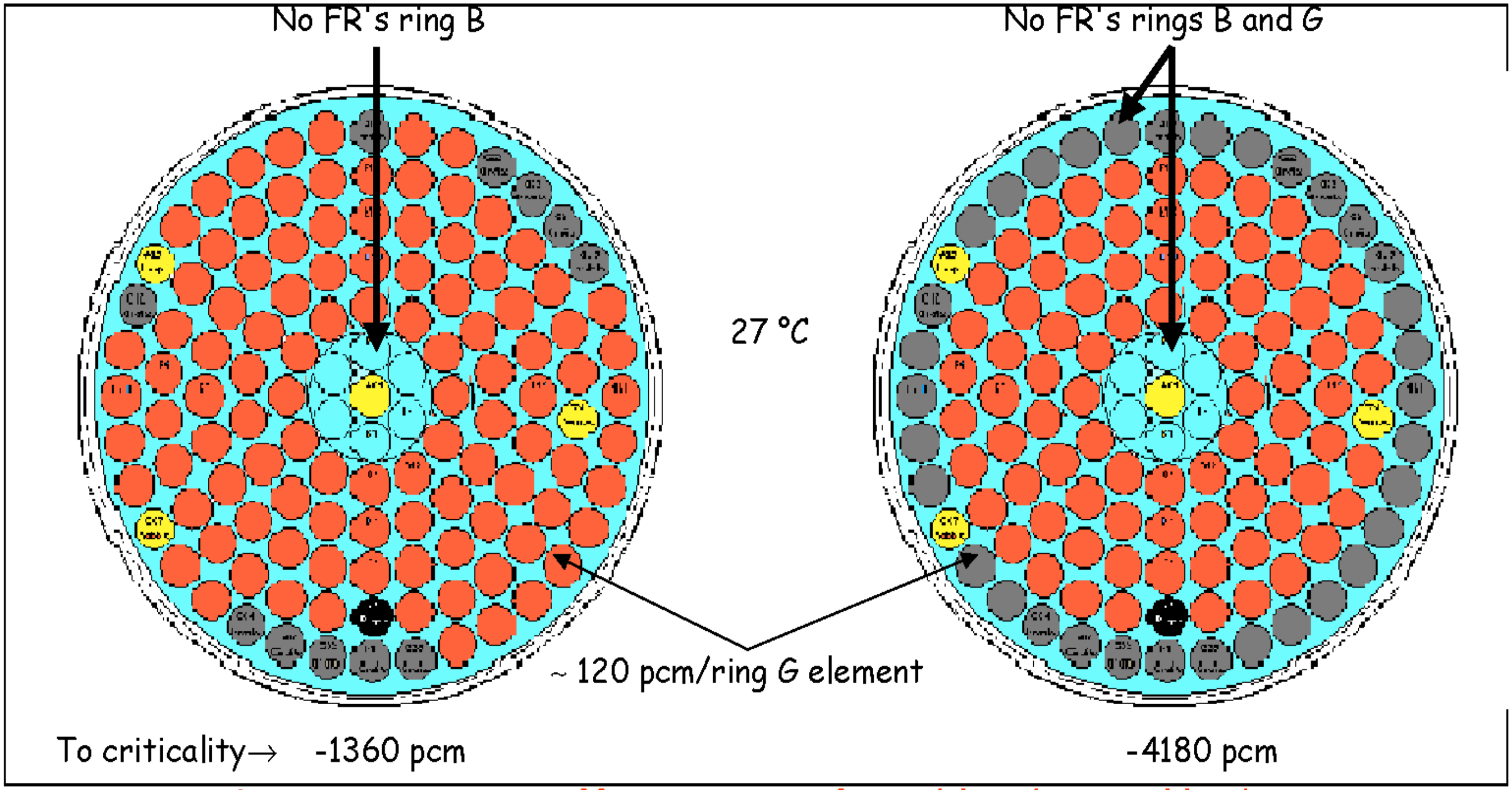


- The dynamic neutronic conditions that can be experimentally realized in TRADE are well representative of dynamic ADS behaviour at higher powers.

TRADE-Neutronic Design

?

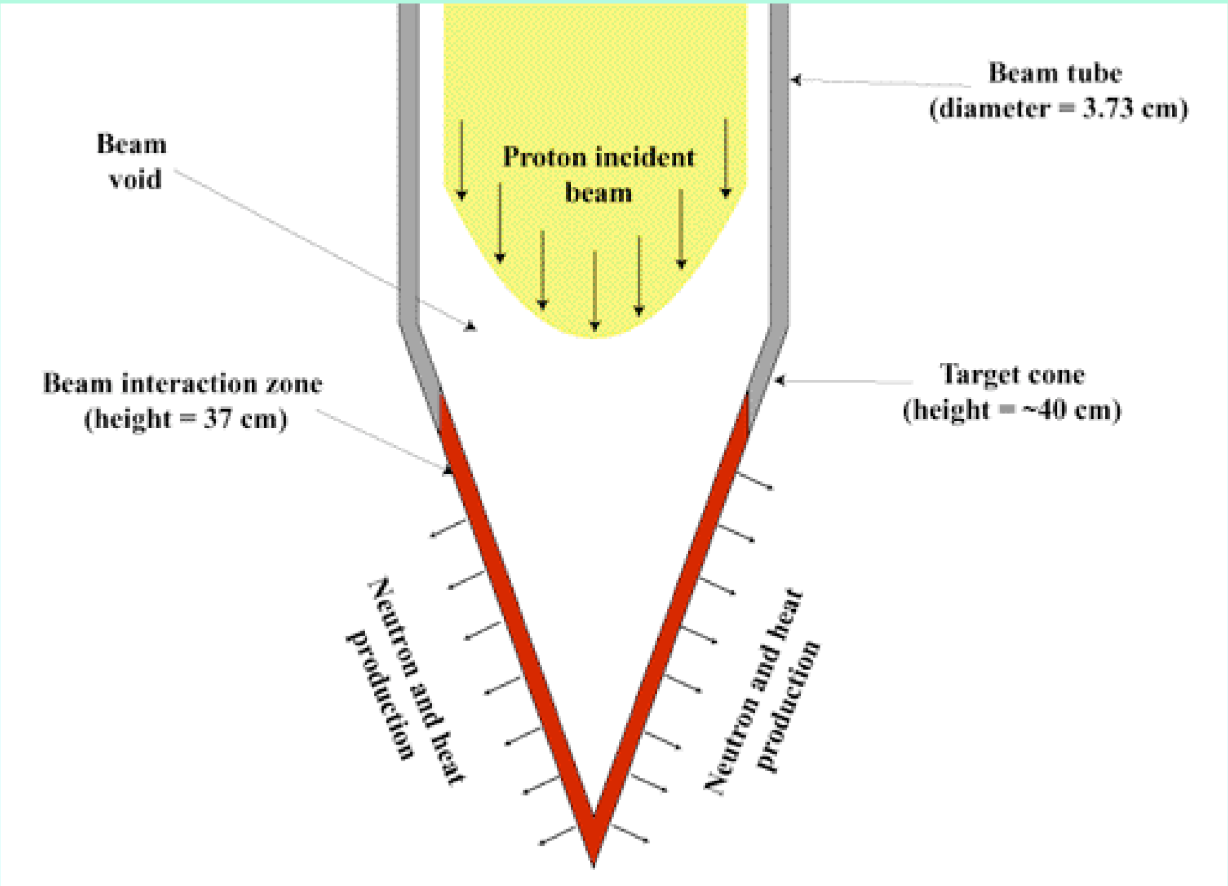
Is it possible to have in TRIGA suitable subcritical core arrangements?



TRIGA seems to offer a variety of suitable subcritical loadings

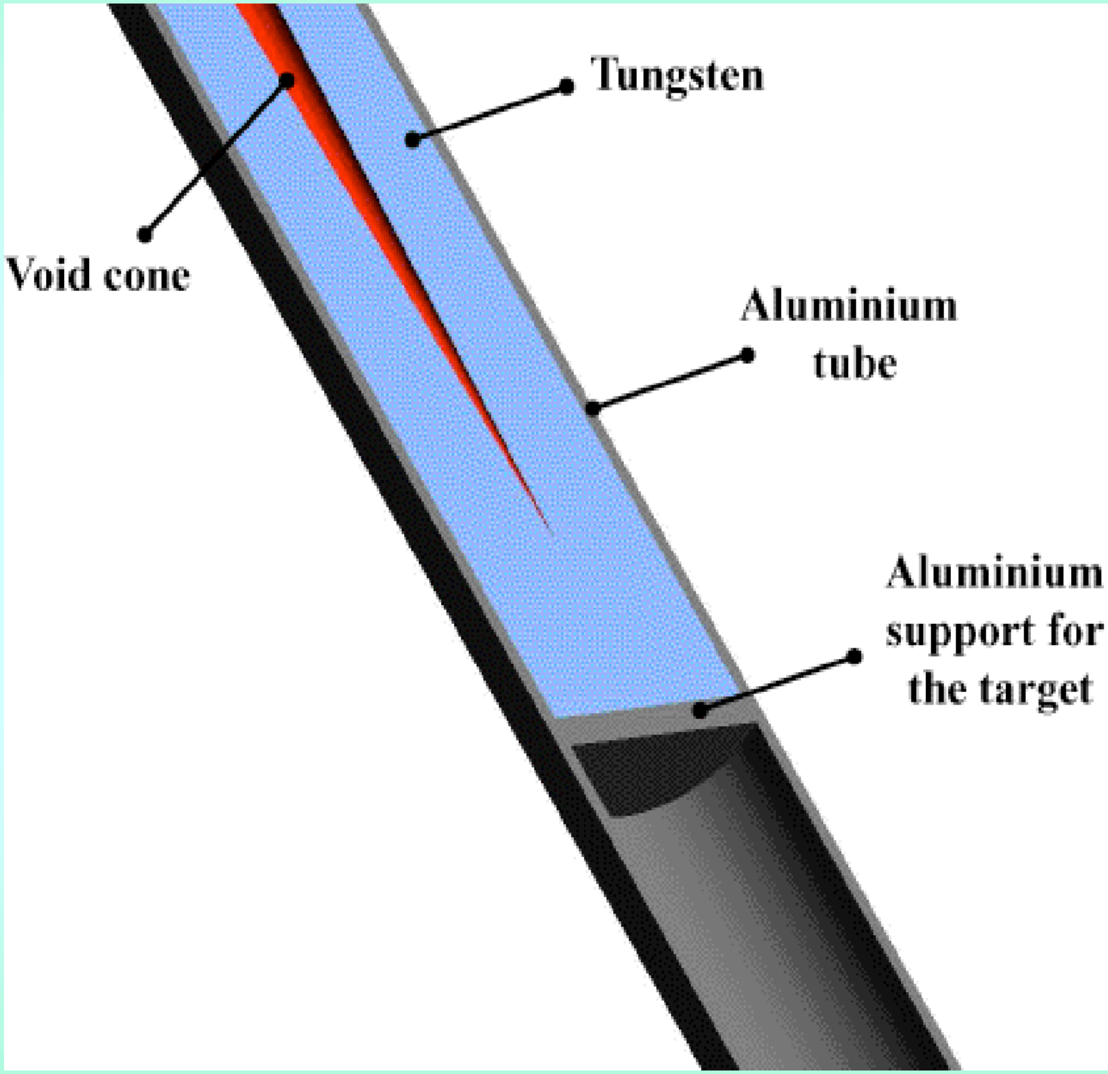
(ranging from 0.90 to 0.99)

Triga target geometry (1)

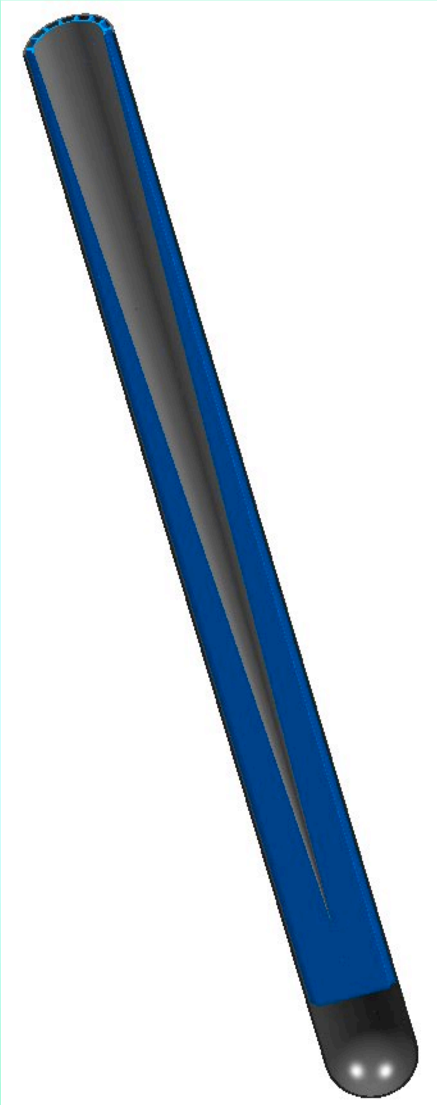


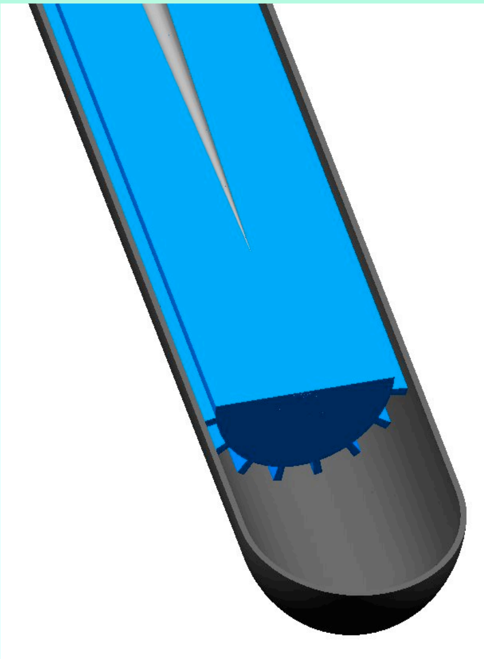
- The target has to fit into a fuel-type pin of 3.73 cm external diameter in the centre of the core.
- To increase the thermal exchange area the target has been designed to be a cone of about the same length as the active part of the core (40 cm).

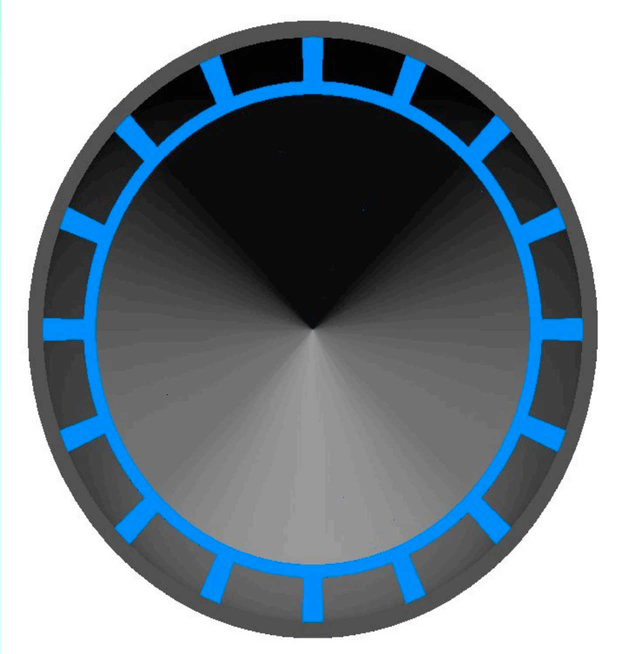
Detail of the bottom part of the natural convection TRIGA target



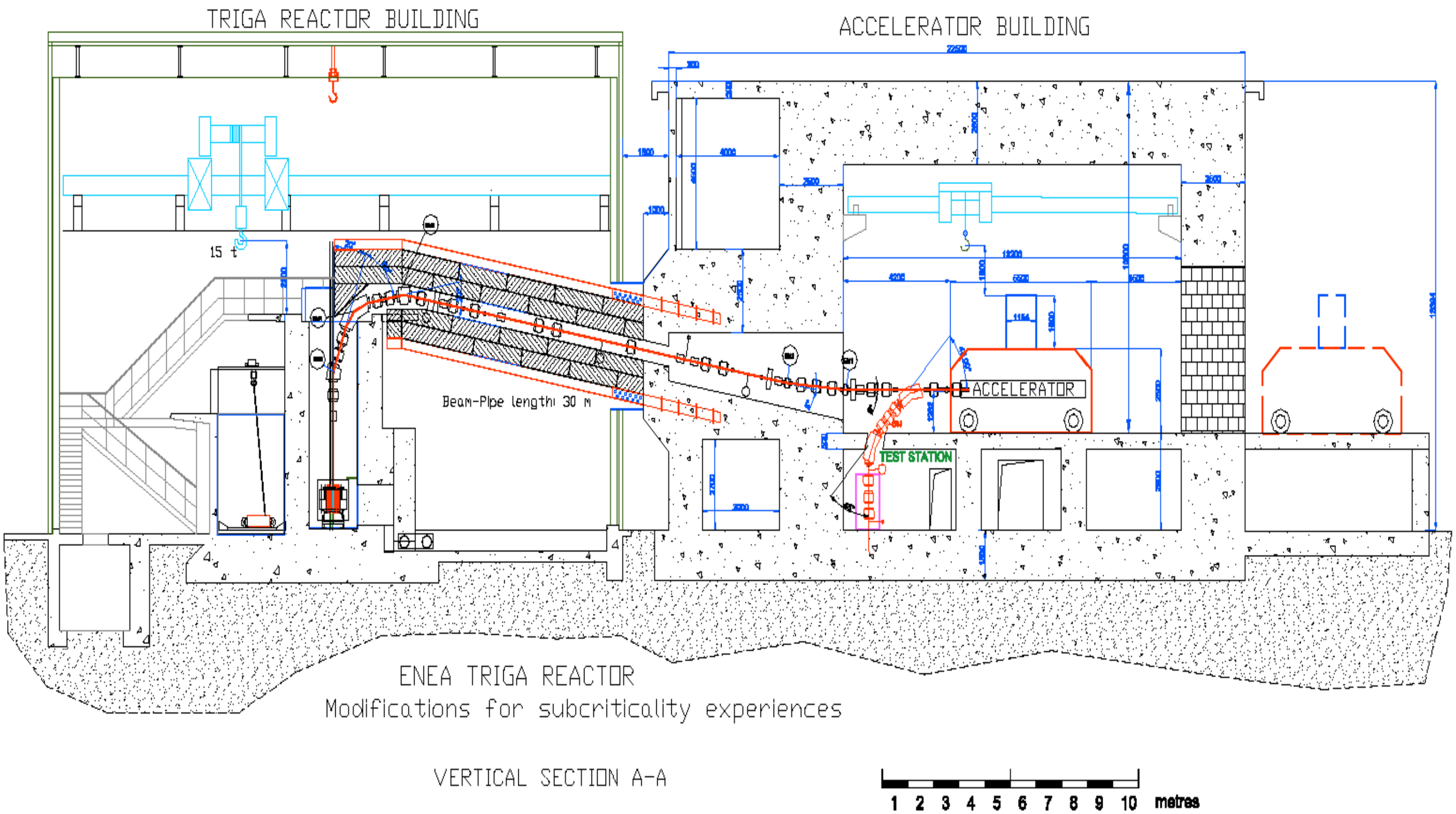
Triga target: forced convection







- 40 cm length, 1.5 cm radius plain cylindrical tungsten block
- 37 cm length, 1.32 base radius void cone.
- 16 fins of 1 mm.

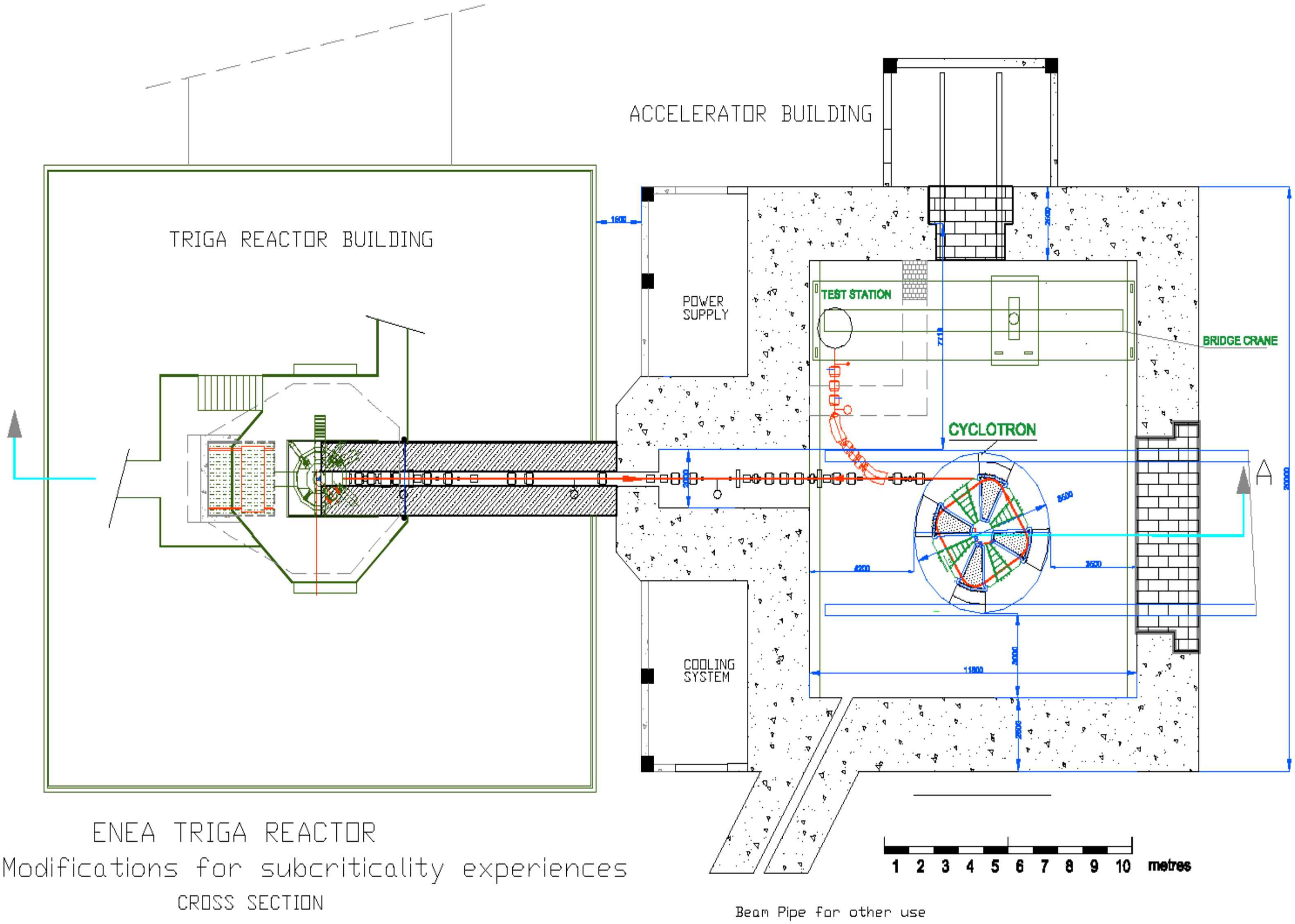


ENEA TRIGA REACTOR

Modifications for subcriticality experiences

VERTICAL SECTION A-A

FIG. 2



ENEA TRIGA REACTOR

Modifications for subcriticality experiences

CROSS SECTION

FIG. 1

Figure 7.1 shows a vertical cross section of the proposed superconducting cyclotron, and the following table 7.1 lists the main characteristics:

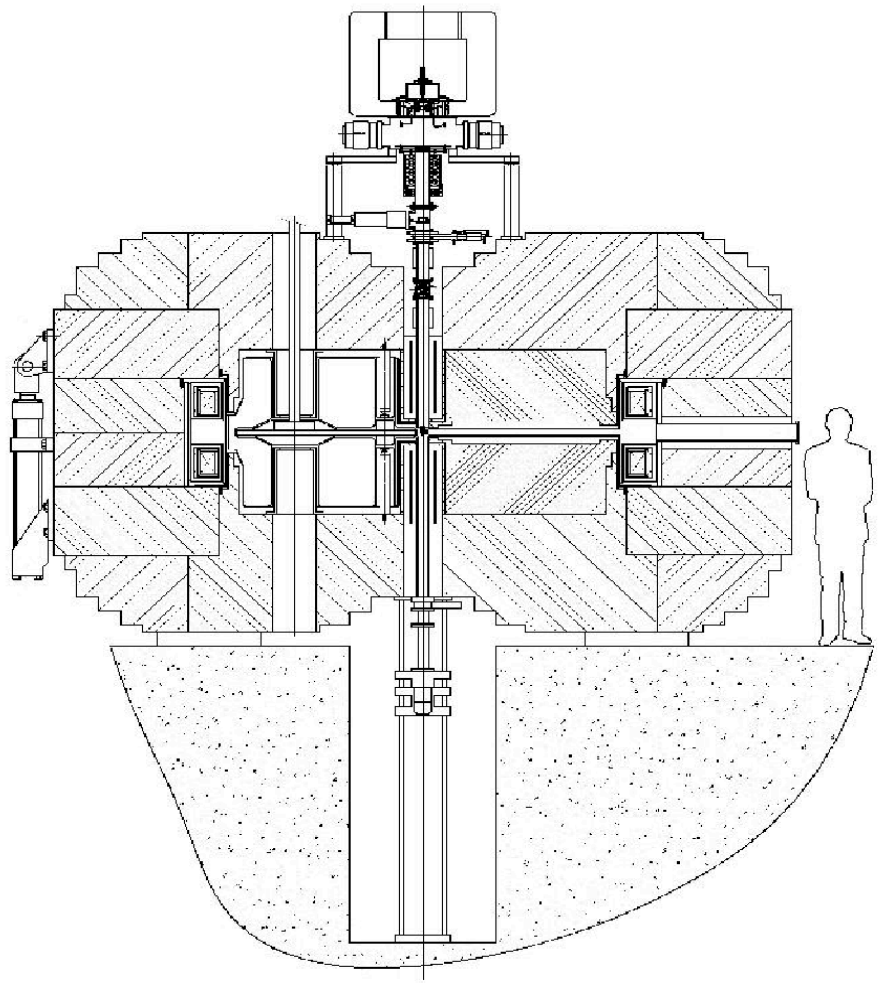


Fig. 7.1 - *AIMA-115N SC-cyclotron: Vertical cross section*

General Planning

- *Preliminary Design*: fall 2002 – mid-2003
- *Detailed Engineering Design*: Second trimester of 2003 – fall 2004
- *Construction (incl. site preparation)*: 2004 – 2005
- *Installation & Commissioning Tests:* over 2006
- *Experiments*: three phases, starting already in 2003 and extending to 2006 (*first coupling at power*) and up to 2009 for follow-up experiments at power

The Experimental Programme

* PHASE I
  - Phase IA: preliminary in-pile measurements → **2nd half of 2002**

  END 2002: FIRST STOP OF TRIGA OPERATION
  - Phase IB: in-pile measurements from **mid-2003 up to mid-2004**

MID-2004: STOP OF TRIGA OPERATION

* PHASE II: Start-up phase over **2nd half of 2006** (after formal ANPA authorisation for operation)

* PHASE III: operation at power **end of 2006.** Experimental programme at power carried out up to **2009**

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Phase IA (4 months)

- Reference configuration (critical or just sc)
- Simulated beam tube/target
- Rod calibration, temperature measurements, feedback measurements, kinetics parameters
- Fission rates, source importance and SI
- Determination of intermediate sc levels (e.g., 500, 3000 and 5000 pcm)

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Phase IB (4 months)

* DT and DD source for transition to accelerator
* Great uncertainties in data above 20 MeV, so this step needed to understand later results
* Validate zero power reactivity measures (PNS)
* Source importance comparisons
* Reactor shut-down after Phase I completion

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Phase II (6 months)

* Startup of the accelerator
* First shot with core loaded with dummy elements
* Characterization of target spallation source
* Gradual fueling of the reactor with measurements along the way

TRADE Working Group---Experiments

Phase III (2 to 3 years)

* The TRADE experiments
* Source importance/current relations

$$i_p \qquad P\frac{v}{\square^{*} Z \square}$$

* Current/power relations

$$\frac{\square P}{P} = \frac{\square S}{S} + \frac{\square k / k}{1 \square k}$$

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Phase III (2)

* Reactivity measurements
* Reaction rates and SI
* Control rod vs. current variation to compensate for reactivity swing---is it feasible at arbitrary sub-criticality levels?
  * TRADE will study the feasibility

TRADE Working Group---Experiments

Phase III (3)

- Feedback effects
  - source domination at lower k
  - relation to sub-criticality level---optimize?
- About 2000 pcm reactivity can be carried in cold/hot TRIGA
  - Investigate dynamics at different sub-criticality levels and powers (25 kW -> 750 kW)

Cost Estimate

- Preliminary overnight vendor cost and manpower evaluation → subject to confirmation when a complete and consistent design will be available
- HARDWARE → **33 M€ + 8.6 M€**
  - Accelerator + Beam Transport Line + Test Station → **29 M€**
  - Plant Modification → **4 M€**
  - ADDITIONAL COSTS → **8.6 M€**
    - TRIGA upgrading → **4.3 M€**
    - Fresh Fuel procurement (optional) → **3.6 M€**
    - Irradiated component disposal and TRADE dismantling → **0.7 M€**
- MANPOWER → **130 man.years** (to be provided in kind by partners and by engineering companies)
- All the costs do not include taxes, contingencies and owner's costs (including TRADE operation)